



Assessing the Sediment Pollution using Heavy Metals Indices in the Nile River Branches in Egypt

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ABSTRACT

Nile river is the main source of fresh water in Egypt. It extends from Aswan to its estuaries at Damietta and Rosetta cities on the Mediterranean coast. The present study aimed to assess some heavy metal pollutants in the hydrosols of the two Nile river branches (Damietta and Rosetta). Twenty sites were chosen for each branch, Fe, Mn, Zn, Cu, Pb, Ni, Cd and Co were measured in the hydrosol. Different heavy metals indices (Enrichment factor, contamination factor, degree of contamination, ecological risk index and geo-accumulation index) were calculated. The results showed that Rosetta branch is more polluted than Damietta branch. Heavy metal indices give an indication for the pollution of the sediments of both branches with Cd which considered as carcinogenic element when its uptake in the food chain increases. The enrichment factor showed that the source of those metals in Nile river branches was from the anthropogenic activities. Cu, Zn, Ni, Pb and Co showed low ecological risk factor in all sites of both branches. The ecological risk index ranged between low, moderate to considerable in most of the studied sites of two branches. It is urgent need for pretreatment of different waste water before discharge in the Nile river.

1. Introduction

In Egypt, the Nile river is the lifeline supplying water to tens of millions people. It flows into Mediterranean Sea by Damietta and Rosetta branches [1]. It receives wastes discharged by industrial, agricultural and domestic activities. Heavy metals have important ecological consideration because of their toxicity and accumulation behavior [2]. The aquatic food chain is ended by the fishes; heavy metals may be accumulated metals in water in which they are below the limit of detection in routine water sample [3].

There are totally 56 larger drains discharging water and transporting pollutants from industrial and settlement areas as well as 72 drains discharging water mainly from agricultural areas along the river, [4]. The exports from agricultural areas and domestic wastes have been the main sources of water pollutants in the Nile river.

Damietta branch is one of the two main branches of the Nile river. This branches passes to cut four governorates with length about 242 km, with average width of 200 m and depth varying from 12 to 20 m [5]. It is important since it acts as a source of water for municipal, agricultural, industrial, navigation and feeding fish farms dispersed between El-Serw to Faraskour region [6].

Rosetta branch is starting from Delta Barrage. It receives relatively high concentrations of nutrients, organic compounds, oil and grease. Major sources of pollution are El-Rahawy drain is one of the main drains, which outlet on Rosetta branch, and receives considerable waste waters from Greater Cairo area, El-Tahrer drain, Sabal drain, Tala drain and Zawiet El-Bahr drain. At Kafr El-Zayat, Rosetta branch receives wastewater from Soda, El-Malia and Kafr El-Zayat companies of pesticides production [7].

Silt deposits which are found in the Nile floodplains have decreased from 24 million tons per year to 2.1 million tons per year. This could be due to construction of the High Aswan Dam in 1964 [8]. This decrease has been responsible for the increase in the use of chemical fertilizers, and consequently resulting in increased values of nutrients in canals and drains. Thus, the bottom sediments of the Nile river Branch subjected to pollution by heavy metals.

Pollution is defined as the change of chemical, physical and biological properties of water and soil, causing preventing its use in the various

applications. The aquatic environments with heavy metals pollution has become a more serious concern nowadays. Trace metals appear in the aquatic environment from both anthropogenic and natural sources. The incorporation into of food chains and concentrated in aquatic organisms to a level that affects their physiological conditions [9]. The aim of this work was to investigate the heavy metals content in the hydrosols of Nile river branches (Damietta and Rosetta Branches) with integrating the indices of heavy metals.

2. Experimental Methods

2.1 The Study Area

Nile river extends from Lake Tanganyika in Tanzania (Lat. 3° S) to the shore of the Mediterranean Sea in Egypt (Lat. 31°15' N) for a length of about 6625 km. After entering Egypt from the Sudan it flows in Upper Egypt (Nile Valley) northwards to the Nile Delta (Lower Egypt). Nile Delta is a triangle longer at the base (220 Km breadth) than the sides (about 170 Km). At the Delta barrages (20 km north of Cairo) the Nile river diverges into two branches. The eastern branch is Damietta Branch, about 239 km in length and located in the area between 30°10'12" N and 31°31'48" N and between 31°07' E and 31°50' E. The western branch is Rosetta branch, about 242 km in length and located in the area between 31.50° N, 30.35° E as shown in Fig. 1 [10].



Fig. 1 Map of Nile Delta showing the sample sites (marked as *) in the two branches of Nile river (Damietta and Rosetta)

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2.2 Sampling and Analysis of Hydrosols

Twenty hydrosol samples were collected randomly from different sites along Damietta and Rosetta Branches as illustrated in Fig. 1. The collection was carried out using a Van-Veen grab coated with polyethylene. Sub-samples were taken from the central part of the grab to prevent contamination.

The samples were retained in self-sealed acid pre-cleaned plastic bags and rinsed with metal-free water. The samples were deep-frozen for analysis. Drying the samples was carried out in the oven at 70 °C and sieved, using 0.75 mm plastic sieve.

The dried samples were digested in a mixture of 3:2:1 HNO₃, HClO₄ and HF acids, respectively according to Oregioni and Astone [11]. Essential heavy metals include Fe, Mn, Pb, Cu, Cd, Zn, Ni and Co were measured using Atomic Absorption Spectrometer (A Perkin-Elmer, Model 2380, USA).

2.3 Heavy Metals Indices

2.3.1 Enrichment Factor (EF)

Iron (Fe) was chosen to be the controlling element [12]. The EF values < 2 indicate that the metal is entirely from crustal materials or natural processes; whereas EF values > 2 reveal that the sources are more likely to be anthropogenic [13].

$$\text{Enrichment Factor} = (\text{M/Fe})_{\text{sample}} / (\text{M/Fe})_{\text{background}} \quad (1)$$

where, M is the metal concentration. The background value is that of average shale [14]. Six categories are recognized: ≤ 1 background concentration, 1-2 depletion to minimal enrichment, 2-5 moderate enrichment, 5-20 significant enrichment, 20-40 very high enrichment and > 40 extremely high enrichment [15].

2.3.2 Contamination Factor (CF)

The CF is the ratio calculated by dividing the concentration of each metal in the sediment by the baseline or background value [16].

$$\text{Contamination Factor (CF)} = \text{C metal} / \text{C background} \quad (2)$$

The following terminologies are used to describe the contamination factor: CF < 1 (low contamination factor); 1 ≤ CF < 3 (moderate contamination factors); 3 ≤ CF < 6 (considerable contamination factors) and CF ≥ 6 (very high contamination factor).

2.3.3 Degree of Contamination (DC)

The Degree of contamination (Dc) is defined as the sum of all contamination factors for a given site [17]:

$$\text{DC} = \sum_{i=1}^n \text{CF}_i \quad (3)$$

where CF is the single contamination factor and n is the count of the elements present. Dc values less than n would indicate low degree of contamination; n ≤ Dc < 2n, moderate degree of contamination; 2n ≤ Dc < 4n, considerable degree of contamination; and Dc > 4n, very high degree of contamination. Where, n=8= the count of the studied heavy metals.

2.3.4 Ecological Risk Assessment

In this study the ecological risk assessment was carried out using two risk indices viz. potential ecological risk index (RI) and pollution load index (PLI).

The potential ecological risk index (RI) of the heavy metals is known as the sum of the risk factors and developed for six toxic metals using equations of Hakanson [16] and Zhu [18].

$$\text{RI} = \sum_{i=1}^n \text{Er} \quad (4)$$

$$\text{Er} = \text{Tr} \times \text{CF} \quad (5)$$

where Er is the single index of ecological risk factor, and n is the count of the heavy metal species, Tr = toxic response factor suggested by Hakanson [17] for six metals Cd (30), Co (5), Cu (5), Pb (5), Ni (5), Zn (1). Er and RI express the potential ecological risk factor of individual and multiple metals, respectively. The following terminology was used for the potential ecological risk factor: Er < 40, low potential ecological risk; 40 ≤ Er < 80, moderate potential ecological risk; 80 ≤ Er < 160, considerable potential ecological risk; 160 ≤ Er < 320, high potential ecological risk; and Er ≥ 320, very high ecological risk. On the other hand, the potential ecological risk index: RI < 150, low ecological risk; 150 ≤ RI < 300, moderate ecological risk; 300 ≤ RI < 600, considerable ecological risk; and RI > 600, very high ecological risk [17].

The pollution load index (PLI) of a single site is the root of number (n) of multiplied together contamination factor (CF) values.

$$\text{PLI} = (\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \dots \times \text{CF}_n)^{1/n} \quad (6)$$

where, n is the number of metals (eight in the present study) and CF is the contamination factor. A PLI value of zero indicates perfection; a value of one indicates the presence of only baseline levels of pollutants, and values above one would indicate progressive deterioration of the site quality [12, 16].

2.3.5 Geo-Accumulation Index (Igeo)

An index of geo-accumulation (Igeo) was originally defined by Muller [19] to determine and define the metal contamination in sediments by comparing current concentrations with pre-industrial levels [20].

$$\text{Igeo} = \text{Log}_2 \left(\frac{\text{C}_n}{1.5\text{B}_n} \right) \quad (7)$$

where, C_n is the concentration of heavy metals in sediments, B_n is the geochemical background value in average shale of element n and 1.5 is the background matrix correction due to anthropogenic influences. The geo-accumulation index (Igeo) was distinguished into seven classes by Buccolieri et al. [21]: Igeo ≤ 0, class 0, unpolluted; 0 < Igeo ≤ 1, class 1, from unpolluted to moderately polluted; 1 < Igeo ≤ 2, class 2, moderately polluted; 2 < Igeo ≤ 3, class 3, from moderately to strongly polluted; 3 < Igeo ≤ 4, class 4, strongly polluted; 4 < Igeo ≤ 5, class 5, from strongly to extremely polluted; and Igeo > 5, class 6, extremely polluted.

3. Results and Discussion

3.1 Environmental Assessment of Heavy Metal Pollution

Some of the metals includes Cu, Fe, Mn, Ni and Zn are essential as micronutrients for the life processes in animals and plants, whereas many other metals such as Cd, Cr, Pb and Co perform specific physiological activities. The metals are non-degradable and can accumulate in the human body, causing damage to nervous system and internal organs [22, 23]. The sequence of heavy metals in the hydrosols of Damietta branch according to concentration was; Fe > Mn > Zn > Pb > Cu > Ni > Co > Cd. While in Rosetta branch it follow the following order; Fe > Zn > Mn > Cu > Pb > Ni > Cd > Co. The range of the metals (μg/g) was as follow: Fe (17-41.55) & (79.05-124.09); Mn (8.58-14.57) & (39.63-43.27); Zn (1.15-5.58); Cu (1.26-4.86) & (12 - 68.14); Pb (1.51-4.54) & (14.82-30); Ni (0.15-2.62) & (1.02 -3.76); Cd (0.12-1.49) & (0.23-3.41) and Co (0.08-1.55) & (0.24-0.85) for Damietta and Rosetta Branches, respectively (Table 1).

Iron being an essential element where it is generally not considered hazardous metal pollutant. At neutral to alkaline pH, Fe is not known to cause toxicity. In the present study, iron concentration was higher than other metals in both branches, indicating that this metal is naturally high in the sediments. However, the concentrations of iron were more in Rosetta branch than Damietta. The range of iron in the present results also is more than those recorded by Abd El-Satar [24].

The lowest values of Fe, Mn and Zn were recorded at the northern part of Damietta branch far away from drainage water, while the highest values of those metals were obtained in sites distributed from Banha and Faraskur cites. In Rosetta branch, the lowest values of Mn and Cu were distributed at the northern part except for iron which showed low value at the southern part at El-Qanatr city. The maximum values of those metals in Rosetta branch were recorded nearby Kafr El-Zayat city; this could be attributed to drainage water either from industrial, agricultural wastes and other anthropogenic activities. The high load of organic matter from these drains aid 66+ to the abundance of those metals [25-27]. It is noticeably that in polluted soils, zinc is generally associated with iron and manganese oxides but can even form complexes with organic compounds [28]. The maximum values of Zn are within the values of CSQG [29] and EU [30].

The highest value of Cu was recorded at site 13 nearby Faraskur. However, the maximum value of Cu in Rosetta branch was recorded near sites affected by industrial and agricultural wastes characterized by high organic matter where copper are strongly adsorbed to organic matter, carbonates and clay [31]. Moreover, applications of agrochemicals can also be considered its possible source. The values of Cu are within the limits CSQG [29] and EU [30], except for its maximum values in Rosetta branch.

For lead, the lowest value was observed at the northern parts of both branches, while its maximum value was obtained at Banha and Kafr El-Zayat cities, this could be corroborated to sewage and industrial wastes according to Bahnasawy et al. [32] who found the same results at the northern part of Manzala Lake. Abdo [33] attributed the high content of lead and cadmium in sediments to the precipitation of organic matter.

Table 1 Heavy metals concentrations (mg/kg) in hydrosol and water samples collected from different ecological sites in Damietta and Rosetta branches

Sites	Damietta Branch								Rosetta Branch							
	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Co	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Co
1	23.87	10.93	2.78	2.60	3.14	1.39	0.14	0.09	84.95	42.52	37.32	28.61	16.14	2.85	0.73	0.73
2	20.89	10.01	3.05	2.74	3.06	1.83	0.74	0.91	80.82	40.44	36.44	21.70	14.90	2.14	2.71	0.39
3	25.83	12.38	4.05	3.84	3.92	2.08	0.79	0.74	83.63	41.20	36.01	27.29	14.82	1.54	0.23	0.79
4	21.10	9.16	4.01	3.83	4.37	2.62	1.37	1.31	79.05	42.61	37.42	27.71	16.24	2.95	0.37	0.82
5	19.53	8.59	2.14	1.26	2.81	1.05	0.80	0.75	85.77	43.18	37.87	22.71	16.23	2.91	0.76	0.75
6	26.24	9.57	3.75	2.99	3.54	0.96	0.73	0.29	88.54	41.47	38.02	29.16	16.74	3.06	1.76	0.70
7	27.78	9.12	4.25	3.63	4.06	1.62	0.12	0.51	91.63	40.61	37.17	38.30	25.89	2.21	1.36	0.43
8	29.79	10.35	4.74	3.91	4.12	1.67	0.13	0.55	107.62	42.26	66.45	50.00	29.04	3.67	0.80	0.75
9	31.75	11.21	5.50	4.42	4.54	1.90	0.16	0.61	97.31	41.82	75.24	62.00	26.23	3.37	0.42	0.44
10	31.92	10.78	4.17	3.51	3.88	1.60	0.79	0.30	99.19	41.31	37.97	38.78	25.94	2.72	3.41	0.48
11	32.90	13.65	4.98	4.33	4.40	1.51	0.31	0.17	95.64	41.38	62.55	48.10	27.94	3.13	2.98	0.24
12	29.62	14.57	4.13	3.37	3.92	1.34	0.35	0.08	121.43	41.70	80.24	44.70	26.38	3.17	2.95	0.26
13	33.40	12.10	5.58	4.86	5.15	2.26	0.45	0.93	124.09	43.27	67.54	68.14	30.00	3.76	2.81	0.80
14	41.55	10.66	4.76	3.93	4.41	1.83	0.13	0.58	121.46	41.97	38.36	40.19	26.81	3.63	1.77	0.73
15	30.45	9.54	3.22	2.39	3.60	0.15	0.38	0.41	122.67	42.30	38.15	19.45	27.11	3.68	1.77	0.76
16	25.81	11.66	2.93	3.11	3.45	1.72	0.13	0.64	107.16	42.03	35.78	15.00	17.42	2.17	1.68	0.42
17	20.59	10.11	1.96	1.78	2.32	0.57	0.68	0.73	103.13	41.52	40.25	17.00	16.00	1.61	0.67	0.25
18	17.00	8.58	1.62	1.31	2.63	1.40	0.69	0.52	99.50	42.71	35.91	12.00	16.89	2.16	2.75	0.76
19	21.94	10.95	2.62	2.41	2.49	0.65	0.64	0.69	97.80	41.16	34.95	20.14	19.00	1.02	1.29	0.85
20	19.78	9.30	1.15	2.97	1.51	1.24	1.49	1.55	89.71	39.63	29.54	17.60	16.46	1.85	1.31	0.64
Mean	26.59	10.66	3.57	3.16	3.57	1.47	0.55	0.62	99.06	41.75	45.16	32.43	21.31	2.68	1.63	0.59
Average shale	47200	850	95	45	20	86	0.3	19	47200	850	95	45	20	86	0.3	19
CSQG (2007)	-	-	200	63	70	50	1.4	40	-	-	200	63	70	50	1.4	40
EU (2002)	-	-	300	40	300	75	0.3	-	-	-	300	40	300	75	0.3	-

CSQG of Agricultural soil: Canadian soil quality guidelines; EU: European Union Standards

Table 2 The categories of enrichment factors (EF) of the heavy metals in Damietta and Rosetta branches

Metal	Damietta		Category	Rosetta		Category
	Min	Max		Min	Max	
Cu	67.87	190.27	Extremely high enrichment	126.50	668.29	Extremely high enrichment
Mn	14.25	28.03	Significant to very high enrichment	19.07	29.94	Significant to very high enrichment
Zn	28.84	94.37	Very high to Extremely high enrichment	154.50	384.16	Extremely high enrichment
Ni	3.44	86.10	Moderate to Extremely high enrichment	7.22	24.02	Significant to very high enrichment
Pb	180.00	488.62	Extremely high enrichment	366.10	666.77	Extremely high enrichment
Co	7.00	194.00	Significant to Extremely high enrichment	5.00	26.00	Significant to very high enrichment
Cd	499.80	11868.21	Extremely high enrichment	681.00	5412.54	Extremely high enrichment

Nickel is a widespread metal in the environment. The highest value of Nickel in Damietta branch was observed at site 4. In Rosetta branch, its lowest value was recorded at Kome Hamada area, but the maximum value was recorded nearby industrial activities. The highest concentrations of Ni could be ascribed to its accumulation at the surface sediments from deposition by the industrial and agricultural activities [34]. Pb and Ni are within the standard limits of CSQG [29] and EU [30].

Cadmium toxicity is expected which can harm production quality due to higher accumulation in edible portion of crops. Cd is mostly related to phosphate fertilizers. The maximum values of Cd in the present study for both branches were obtained nearby the areas mostly affected by agricultural wastes. Pesticides may also contribute to the high Cd content in the sediments of aquatic bodies [35]. It can be considered as one of the most dangerous elements on aquatic life and humans. The maximum values of cadmium in both branches were higher than the limits of CSQG [29] and EU [30].

In present investigation, the highest value of Co was recorded at the northern parts of both branches; this could be attributed to anthropogenic activities in these areas especially the industrial wastes [36]. The main source of cobalt inputs in the soil are traffic activities, industrial effluents and application of sewage sludge [37]. Approximately, 33-44% of Co occurs as stable organic complexes and is unavailable to aquatic or soil-dwelling organisms. The values of cobalt in the present results are within the limits of CSQG [29].

3.2 Heavy Metals Indices

3.2.1 Enrichment Factor (EF)

The enrichment factors of heavy metals in Damietta and Rosetta branches were as shown in Fig. 2, 3 and Table 2. The sequence of EF in Damietta branch was Cd > Pb > Co > Cu > Zn > Ni > Mn. On the other hand, the sequence of it in Rosetta branch was as follows; Cd > Pb > Cu > Zn > Mn > Co > Ni. The enrichment factor of heavy metals in both branches is >2, indicated that the source of those metals was from anthropogenic activities. It is obvious that Cd is most abundant in the two branches; this could be attributed to agricultural wastes and phosphatic fertilizers. Ni in

hydrosols of Rosetta and Mn in hydrosols of Damietta branch showed the lowest appearance.

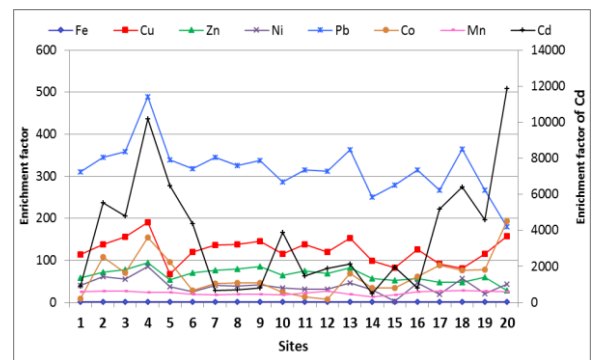


Fig. 2 The enrichment factors of heavy metals in the hydrosols of Damietta Branch

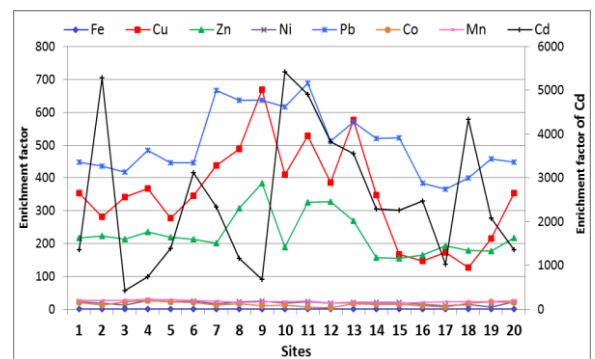


Fig. 3 The enrichment factor of heavy metals in the hydrosols of Rosetta Branch

Table 3 The contamination factors (CF), pollution load index (PLI) and degree of contamination (DC) of heavy metals in the hydrosols of both Damietta and Rosetta branches

Sites	Damietta Branch										Rosetta Branch													
	Contamination factors										PLI	DC	Contamination factors										PLI	DC
	Fe	Cu	Zn	Ni	Pb	Co	Cd	Mn	Fe	Cu			Zn	Ni	Pb	Co	Cd	Mn						
1	0.001	0.058	0.029	0.020	0.157	0.004	0.460	0.013	0.02	1.00	0.002	0.636	0.393	0.042	0.807	0.038	2.449	0.050	0.13	4.42				
2	0.000	0.061	0.032	0.027	0.153	0.048	2.453	0.012	0.04	3.00	0.002	0.482	0.384	0.031	0.745	0.021	9.045	0.048	0.13	10.76				
3	0.001	0.085	0.043	0.031	0.196	0.039	2.627	0.015	0.05	3.31	0.002	0.606	0.379	0.023	0.741	0.041	0.759	0.048	0.10	2.60				
4	0.000	0.085	0.042	0.038	0.218	0.069	4.557	0.011	0.05	5.22	0.002	0.616	0.394	0.043	0.812	0.043	1.232	0.050	0.12	3.19				
5	0.000	0.028	0.023	0.016	0.140	0.040	2.677	0.010	0.03	3.11	0.002	0.505	0.399	0.043	0.811	0.040	2.535	0.051	0.13	4.38				
6	0.001	0.067	0.039	0.014	0.177	0.015	2.433	0.011	0.03	2.96	0.002	0.648	0.400	0.045	0.837	0.037	5.857	0.049	0.14	7.88				
7	0.001	0.081	0.045	0.024	0.203	0.027	0.383	0.011	0.03	0.97	0.002	0.851	0.391	0.032	1.294	0.023	4.541	0.048	0.14	7.18				
8	0.001	0.087	0.050	0.025	0.206	0.029	0.440	0.012	0.03	1.07	0.002	1.111	0.699	0.054	1.452	0.039	2.651	0.050	0.17	6.06				
9	0.001	0.098	0.058	0.028	0.227	0.032	0.543	0.013	0.04	1.24	0.002	1.378	0.792	0.050	1.312	0.023	1.404	0.049	0.15	5.01				
10	0.001	0.078	0.044	0.024	0.194	0.016	2.630	0.013	0.04	3.24	0.002	0.862	0.400	0.040	1.297	0.025	11.374	0.049	0.16	14.05				
11	0.001	0.096	0.052	0.022	0.220	0.009	1.033	0.016	0.04	1.75	0.002	1.069	0.658	0.046	1.397	0.013	9.934	0.049	0.17	13.17				
12	0.001	0.075	0.043	0.020	0.196	0.004	1.180	0.017	0.03	1.86	0.003	0.993	0.845	0.047	1.319	0.014	9.847	0.049	0.17	13.12				
13	0.001	0.108	0.059	0.033	0.257	0.049	1.500	0.014	0.05	2.28	0.003	1.514	0.711	0.055	1.500	0.042	9.354	0.051	0.22	13.23				
14	0.001	0.087	0.050	0.027	0.221	0.030	0.440	0.013	0.04	1.10	0.003	0.893	0.404	0.053	1.341	0.038	5.897	0.049	0.17	8.68				
15	0.001	0.053	0.034	0.002	0.180	0.022	1.267	0.011	0.02	1.74	0.003	0.432	0.402	0.054	1.355	0.040	5.894	0.050	0.16	8.23				
16	0.001	0.069	0.031	0.025	0.173	0.034	0.440	0.014	0.03	1.04	0.002	0.333	0.377	0.032	0.871	0.022	5.612	0.049	0.12	7.30				
17	0.000	0.040	0.021	0.008	0.116	0.038	2.257	0.012	0.03	2.68	0.002	0.378	0.424	0.024	0.800	0.013	2.249	0.049	0.10	3.94				
18	0.000	0.029	0.017	0.021	0.132	0.027	2.310	0.010	0.03	2.74	0.002	0.267	0.378	0.032	0.844	0.040	9.152	0.050	0.13	10.77				
19	0.000	0.054	0.028	0.009	0.124	0.036	2.137	0.013	0.03	2.60	0.002	0.448	0.368	0.015	0.950	0.045	4.302	0.048	0.12	6.18				
20	0.000	0.066	0.012	0.018	0.075	0.081	4.973	0.011	0.03	5.38	0.002	0.391	0.311	0.027	0.823	0.034	4.356	0.047	0.12	5.99				
Mean	0.001	0.070	0.038	0.022	0.178	0.032	1.837	0.013	0.04	2.42	0.002	0.721	0.475	0.039	1.065	0.032	5.422	0.049	0.143	7.81				

Table 4 Ecological risk factor (Er) and ecological risk index (RI) of heavy metals in the hydrosols of Damietta and Rosetta branch

Sites	Damietta Branch										Rosetta Branch											
	Ecological risk factor (Er)										RI	Ecological risk factor (Er)										RI
	Fe	Mn	Cu	Zn	Ni	Pb	Co	Cd	Fe	Mn		Cu	Zn	Ni	Pb	Co	Cd					
1	-	-	0.29	0.03	0.10	0.79	0.02	13.80	15.02	-	-	3.18	0.39	0.21	4.04	0.19	73.47	81.48				
2	-	-	0.31	0.03	0.14	0.77	0.24	73.59	75.07	-	-	2.41	0.38	0.16	3.73	0.11	271.35	278.13				
3	-	-	0.43	0.04	0.16	0.98	0.20	78.81	80.61	-	-	3.03	0.38	0.12	3.71	0.21	22.77	30.20				
4	-	-	0.43	0.04	0.19	1.09	0.35	136.71	138.80	-	-	3.08	0.39	0.22	4.06	0.22	36.96	44.92				
5	-	-	0.14	0.02	0.08	0.70	0.20	80.31	81.45	-	-	2.53	0.40	0.22	4.06	0.20	76.05	83.44				
6	-	-	0.34	0.04	0.07	0.89	0.08	72.99	74.39	-	-	3.24	0.40	0.23	4.19	0.19	175.71	183.95				
7	-	-	0.41	0.05	0.12	1.02	0.14	11.49	13.21	-	-	4.26	0.39	0.16	6.47	0.12	136.23	147.62				
8	-	-	0.44	0.05	0.13	1.03	0.15	13.20	14.99	-	-	5.56	0.70	0.27	7.26	0.20	79.53	93.51				
9	-	-	0.49	0.06	0.14	1.14	0.16	16.29	18.27	-	-	6.89	0.79	0.25	6.56	0.12	42.12	56.73				
10	-	-	0.39	0.04	0.12	0.97	0.08	78.90	80.50	-	-	4.31	0.40	0.20	6.49	0.13	341.22	352.74				
11	-	-	0.48	0.05	0.11	1.10	0.05	30.99	32.78	-	-	5.35	0.66	0.23	6.99	0.07	298.02	311.30				
12	-	-	0.38	0.04	0.10	0.98	0.02	35.40	36.92	-	-	4.97	0.85	0.24	6.60	0.07	295.41	308.12				
13	-	-	0.54	0.06	0.17	1.29	0.25	45.00	47.29	-	-	7.57	0.71	0.28	7.50	0.21	280.62	296.89				
14	-	-	0.44	0.05	0.14	1.11	0.15	13.20	15.08	-	-	4.47	0.40	0.27	6.71	0.19	176.91	188.94				
15	-	-	0.27	0.03	0.01	0.90	0.11	38.01	39.33	-	-	2.16	0.40	0.27	6.78	0.20	176.82	186.63				
16	-	-	0.35	0.03	0.13	0.87	0.17	13.20	14.74	-	-	1.67	0.38	0.16	4.36	0.11	168.36	175.03				
17	-	-	0.20	0.02	0.04	0.58	0.19	67.71	68.74	-	-	1.89	0.42	0.12	4.00	0.07	67.47	73.97				
18	-	-	0.15	0.02	0.11	0.66	0.14	69.30	70.36	-	-	1.34	0.38	0.16	4.22	0.20	274.56	280.85				
19	-	-	0.27	0.03	0.05	0.62	0.18	64.11	65.25	-	-	2.24	0.37	0.08	4.75	0.23	129.06	136.72				
20	-	-	0.33	0.01	0.09	0.38	0.41	149.19	150.40	-	-	1.96	0.31	0.14	4.12	0.17	130.68	137.37				
Mean	-	-	0.35	0.04	0.11	0.89	0.16	55.11	56.66	-	-	3.61	0.48	0.20	5.33	0.16	162.67	172.43				

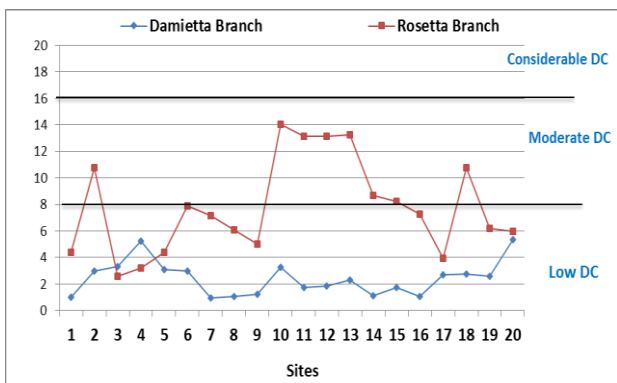


Fig. 4 The degree of contamination (DC) of heavy metals in the hydrosols of Damietta and Rosetta branches

3.2.2 Contamination Factor (CF)

The CF of all metals in Damietta branch showed low contamination factor except for Cd which showed low CF in site 1, moderate CF in sites 2, 3, 5, 6, 10, 11, 12, 13, 15, 17, 18, 19 and considerable CF in site 4 and site

20 which may be exposed to drainage water especially agricultural wastes (Table 3).

In Rosetta Branch, Cu showed low CF in most sites and moderate CF in site 8, 9, 11 and 13. For Zn, Ni, Co and Mn, they showed low CF in all locations (Table 3). The CF of Pb ranged between low and moderate CF. For Cd, the CF fluctuated between low in site 3; moderate in sites 1, 4, 5, 9 and 17; considerable in sites 6, 14, 15, 16, 19 and 20; and very high contamination factor in site 2.

3.2.3 Degree of Contamination (DC)

The DC in all sites was showed low range ($8 \leq DC < 16$) in Damietta branch, where the values rang is between 0.97 in site 7 and 5.22 in site 4 with mean value of 2.42. In Rosetta branch, the DC in all sites ranged between low to moderate DC ($16 \leq DC < 32$), where the values rang is between 2.60 in site 3 and 14.05 in site 10 with mean value 7.81 (Table 3 and Fig. 4).

3.2.4 Ecological Risk Assessment

3.2.4.1 The Ecological Risk Factor (Er)

The Er of the heavy metals in the investigated sites in two branches is given in Table 4. Both Fe and Mn showed insignificant ecological risk factor, but Cu, Zn, Ni, Pb and Co showed low ecological risk factor ($Er < 40$)

in all sites of both branches, except Cd. Cadmium has no biological function and it is highly toxic to living organism [38]. Toxic response factor (Tr) for Cd was high (30) as compared to Tr of Cr, Cu, Zn, and Pb which along with relatively low background value (0.12) is responsible for high Cd Er [37].

In Damietta branch, Cadmium showed low potential ecological factor in sites 1, 7, 8, 9, 11, 12, 14, 15 and 16, moderate potential ecological risk factor in sites 2, 3, 6, 10, 13, 17, 18 and 19 as well as in sites 4, 5 and 20 showed considerable potential ecological risk factor, whereas in Rosetta Branch for Cd, it showed low potential ecological factor in sites 3 and 4, moderate potential ecological risk factor in sites 1, 5, 8, 9, and 17, considerable potential ecological risk factor in sites 7, 19 and 20, high potential ecological risk factor in sites 2, 6, 11, 12, 13, 14, 15, 16 and 18 as well as in site 10 showed very high ecological risk factor.

3.2.4.2 The Ecological Risk Index (RI)

The RI of the studied heavy metals in both branches is given in Table 4 and Fig. 5. It is clear that all the sites showed low ecological risk index in Damietta branch, while in Rosetta branch RI classified in three risk categories: low ecological risk index in sites 1, 3, 4, 5, 7, 8, 9, 17, 19 and 20, moderate potential ecological risk index in sites 2, 6, 13, 14, 15, 16 and 18 as well as considerable potential ecological risk index in sites 10, 11 and 12.

3.2.4.3 Pollution Load Index (PLI)

The PLI of heavy metals in the hydrosediments of both branches was lower than 1. In Damietta branch their values ranged from 0.02 in site 1 and 15 to 0.05 in sites 3, 4 and 15 with mean value of 0.04. On the other hand, the values ranged from 0.10 in site 3 and 17 to 0.22 in site 13 with mean value 0.143 in Rosetta branch. The pollution load index of heavy metals indicated no pollution by metals (Table 3 and Fig. 6). Mean PLI value recorded in this study was far lower than the threshold (<1), indicating the absence of baseline pollutants or loads near to background levels [16].

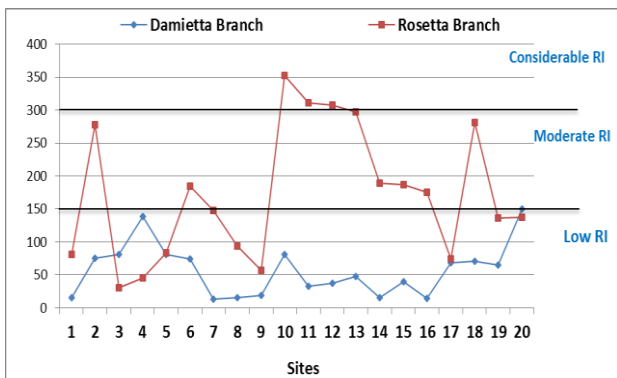


Fig. 5 The ecological risk index (RI) of heavy metals in the hydrosediments of Damietta and Rosetta branches

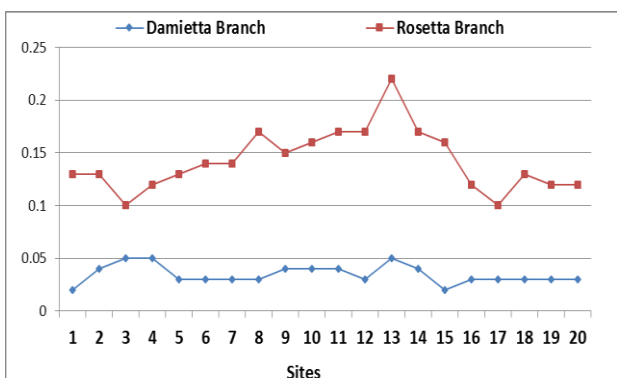


Fig. 6 The pollution load index (PLI) of heavy metals in the hydrosediments of Damietta and Rosetta branches

3.2.5 Geo-Accumulation Index (Igeo)

The geoaccumulation index of heavy metals in the hydrosediments of both branches showed that the sediments were more polluted with Cd (Figs. 7 and 8). This could be attributed to the uses of phosphatic fertilizers in agricultural activities. NYSDEC [39] and Audry et al [40] revealed that the river sediments which contain Cd could be severely harmful to the aquatic biota.

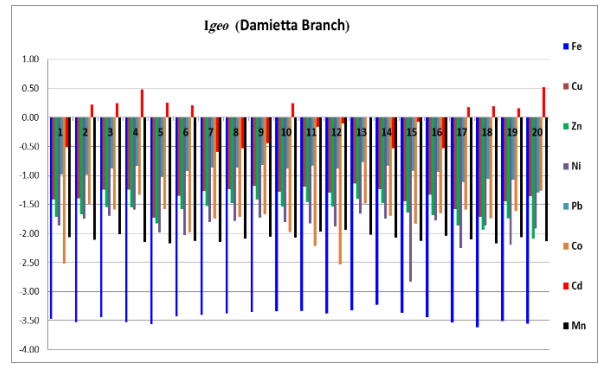


Fig. 7 The geo-accumulation index (Igeo) of heavy metals in the hydrosediments of Damietta branch

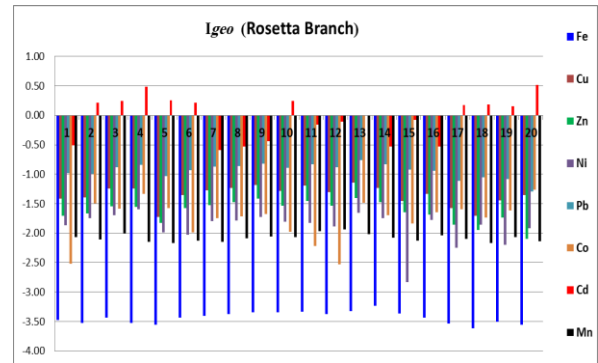


Fig. 8 The geo-accumulation index (Igeo) of heavy metals in the hydrosediments of Rosetta branch

4. Conclusion

Cd is the most serious pollutant in both of Damietta and Rosetta branches. However, its concentration in Rosetta branch raises the alarm strongly toward the official agencies to confront this dangerous element to the aquatic life as well as human. It is recommended, the waste water especially that for the industrial companies should be pretreated before discharging to Nile river. The concerned authorities must establish keep eyes on the different companies as well as the sewage effluent sources.

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